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# Comparison of Recorded Bulk Temperatures in a Potato Store with Simulation Model Output

I A BARRIE

## Summary

Temperatures were recorded in a 600 tonne insulated ware potato store in Shropshire during the winter of 1986/87. Measurements were also made of surface moisture on the stack.

The recorded temperatures are compared to predictions from a ware potato store simulated temperature model (which assumes automatic ambient air cooling), although the ventilation in this store was operated manually. There was no additional insulation applied directly to the stack surface.

## Store Design and Management

Following a pilot study during the winter of 1985/86 when near freezing temperatures were recorded in the ware store, the grower decided to substantially improve the level of insulation. Polyurethane foam, to a depth of 50 mm, was sprayed onto the corrugated upper walls and roof area. Additional insulation (plyboard backed with 25 mm of expanded polystyrene) was fixed to the lower block-built walls, to the depth of the stack, and new doors were fitted (plyboard backed with 25 mm expanded polystyrene). The floor, 150 mm concrete, was unaltered - see table 1.

Table 1. Thermal Insulation/U-values of ware store

| | Material | % total area | U-value |
|---|---|---|---|
| Upper walls and roof | Asbestos sheets 50 mm foam | 70 | 0.42 |
| Crop retaining walls | 9" block 25 mm foam on ply | 25 | 0.74 |
| Doors | 25 mm foam on ply | 5 | 0.96 |
| Floor | 150 mm concrete | - | - |

U value for whole store = 0.53 $w/m^2/°C$. (ADAS 1986)

FH2B

The store was divided into two equal sections by a central main air duct, leading to above floor lateral vents at 2.3 m spacings. Ambient air cooling was provided by a 9.1 $m^3/s$ fan under manual control. There was no facility for re-circulation. Temperature recordings were maintained in only one section, which was three quarters filled with approx. 200 tonnes of main crop Romano during October 1986. The tubers were dry, soil free and sound on loading and the final dimensions of the stack were 3.7 m (deep) by 12.2 m by 8.2 m. The sprout suppresant CIPC (chloropropham) was applied to the stack as a gas on 1st December.

Temperature Recording

Thermistor temperature sensors were located within the stack while the store was being filled. A Grant Squirrell data logger was installed on 14 November 1986 and set to record at 30 minute intervals. Initially, the recording locations were a) close to the floor, near to the wall on the left side. b) in a lateral ventilation channel. c) central to the top of the stack.

The first 2 weeks of recording is given in fig. 1. This shows stack temperatures of around 10°C, gradually falling to around 7°C. The centre of the stack tended to be warmer than the edge by up to 2°C. The effect of ambient air ventilation can be seen on the 16th, 19th and 21st. The rise in temperature at point 4 on the 16th is likely to be due to warm air being forced up from the centre of the stack. The surface wetness sensor reads the equivalent of 0°C when dry so it can be seen that surface moisture persisted for the whole period, bar short spells during ventilation. There was no forced ventilation after 7 January 1987, after which the store was frequently opened for grading and removal of tubers to the farm shop.

During the recording period, wear and tear on the equipment was high, but there was always a minimum of 2 sensors functioning. These seldom differed by more than 1°C so they have been averaged and are plotted against an ambient temperature as weekly means - fig. 2. The stack temperatures were remarkably stable, even during the period of very cold (and windy) weather during mid January.

## Store Temperature Simulation Model

The model* was run for the Met. Station at Shawbury, Shropshire, approx 15 km North West of the ware store - see fig. 3. Details of the model are listed in the Annex but two of its assumptions make it inappropriate to this particular ware store, primarily

a. The model assumes that the internal wall temperature is the same as that of the ambient air. This may well be true for poorly insulated stores, but the comparison between actual and model temperatures indicates that well insulated stores barely respond to changes in ambient temperatures.

b. The model assumes ambient air cooling for every possible hour - given the restraints due to freezing air and a suitable temperature differential stack/ambient. This ware store was ventilated manually, but had a fan capacity appropriate for late storage of the full store.

The assumption "a" explains most of the differences between actual stack temperatures and the model output. This has resulted in the model over-responding to warmer ambient conditions. With the onset of cooler weather, the assumed ventilation with ambient air correctly reduces the stack temperature quickly on many occasions.

The metabolic heat generation by the tubers is assumed to vary, depending on stack temperature, and in general the stack temperature is raised by 1°C in 3 days. Published values for metabolic heat production (MAFF, 1979) indicate that at 5°C the rate is 9 w/tonne, rising to 15 w/tonne at a stack temperature of 15°C. At 10 w/tonne the stack would warm by 1°C in rather more than 4 days (assuming the specific heat of the tubers to be 3.6 kJ/kg/°C.)

## Conclusions

The ware potato store under study has a high level of insulation and consequently a low rate of heat loss - its U-value of 0.53 $w/m^2/°C$ approaches the specification required for long term storage (U-value 0.45 to 0.55 $w/m^2/°C$) when the potential for solar gain in April and May has to be considered. A store designed for frost protection alone needs a lower level of insulation leading to a higher rate of heat loss - U-value 1.4 $w/m^2/°C$. It is not therefore surprising that the control of stack temperature was excellent, even during the coldest spell of the winter.

*Developed by Agromet, Cambridge, based on theory by Smith (1968).

The simulation model is an excellent example of how a meteorological solution can be applied to an agricultural problem, but the existing limited options available for specifying a variety of store types restrict the application of the model. In particular, the present parameters appear to include a low specification for insulation (being strongly influenced by ambient temperatures) and a high specification of ventilation (automatic ambient air cooling).

Thus the basic principles are sound but the physics of the heat exchange processes are inflexible.

If the model were improved then the following applications could be considered:

1. High specification stores:- Long term storage into spring/early summer - expressed as both a climatology and real-time operational outputs.

2. Low specification stores:- Frost protection statistics and simple preventative measures (straw covering) - expressed as both a climatology and real-time operational outputs.

3. Field clamps:- as 2.

The service could be offered to the Potato Marketing Board, Design Consultants (including ADAS), processors and growers' cooperatives for systems which are dependant on ambient temperatures. Incorporation of seven day forecast air temperatures into the model would produce valuable planning advice on the future trend of stack temperatures. Periods when stores were likely to run below target, as opposed to maintaining target temperature, could be differentiated, ie. from fig. 3 compare periods from 11 Dec and 7 Jan.

Any comments or suggestions should be referred to the author.

Met Unit
MAFF
Wolverhampton
June 1987

## References

ADAS, 1986 — Insulation of Farm Buildings. Leaflet P851

MAFF, 1979 — Refrigerated Storage of Fruit and Vegetables. Reference Book 324. HMSO.

Smith, C.V. 1969 — On the Temperature Control of Potato Bulks (and chitting houses) by Ventilation. Agricultural Memorandum 271.

## Acknowledgements

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Key Words: potatoes, storage, ventilation, insulation.

Annex

SIMULATION OF POTATO STORE TEMPERATURES

As an aid to the management of potato stores, a computer program is being developed by ADAS Agro meteorologists to simulate temperature changes in potato stores. The program uses current recordings up to the day previous to each run of the program.

A simple model of heat exchange within the stored bulk and between the bulk and ventilating air is used. The temperature of the bulk is ventilated whenever suitably cool air is available.

The need for additional cooling by refrigeration, especially in autumn and spring, can be examined in the light of simulated performance of the store when only ambient air is used to control the temperature; the various assumptions made in the model are described

OBJECTIVE

To reduce the temperature of potatoes placed in store in mid-September at a temperature of 15°C to a target temperature of 4.5 °C and to maintain a bulk temperature of between 2°C and 6°C until mid-May.

ASSUMPTIONS

1. The potatoes are stored in bulk to a depth of between 3 m and 5 m.

2. The metabolic (respiration) heat output of the potatoes is such that, in the absence of and cooling by ventilation, the temperature of the stored bulk will rise by 1°C in about 3 days.

3. Ventilation of the bulk is at a rate of 170 $m^3 t^{-1} h^{-1}$, equivalent to 100 cfm per ton.

4. The temperature of the ventilating air should be between 2°C and 4.5°C colder than the bulk but not colder than -1°C.

5. The temperature of the ventilating air is raised by 1°C due to passage through the fan system.

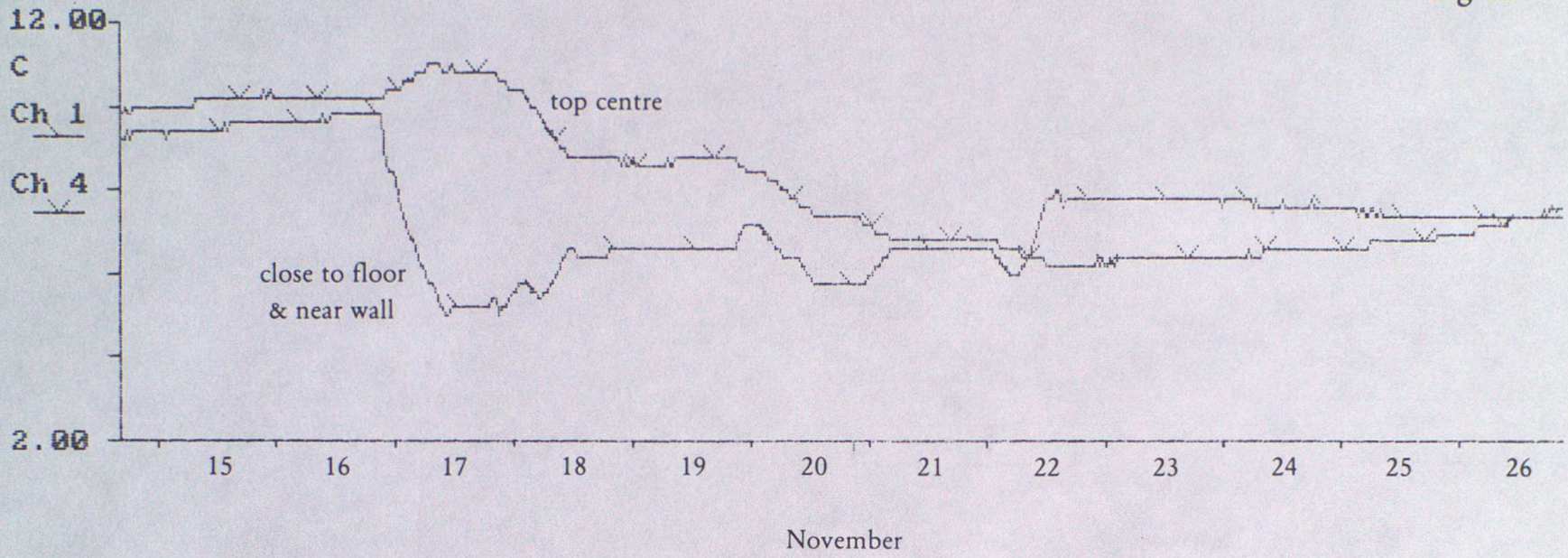
## THE MODEL

Each hour, the decision whether or not to ventilate is made by comparing the calculated bulk temperature with the target temperature and that of the outside air. The outside air temperature for each hour is estimated by applying mathematical relationships to the observed values of daily maximum and minimum temperatures from a nearby meteorological site. After allowing for the various heat exchange processes, the bulk temperature at the end of the hour is estimated - this temperature is then used as the initial bulk temperature for the next hour's simulation.

When auxiliary refrigeration is available, it will be used to cool the residual air inside the store. This air (assumed to be at the same temperature as the bulk) will be cooled to not more than 4.5°C below the bulk temperature - but not colder than -1°C - and then recirculated to control the bulk temperature.

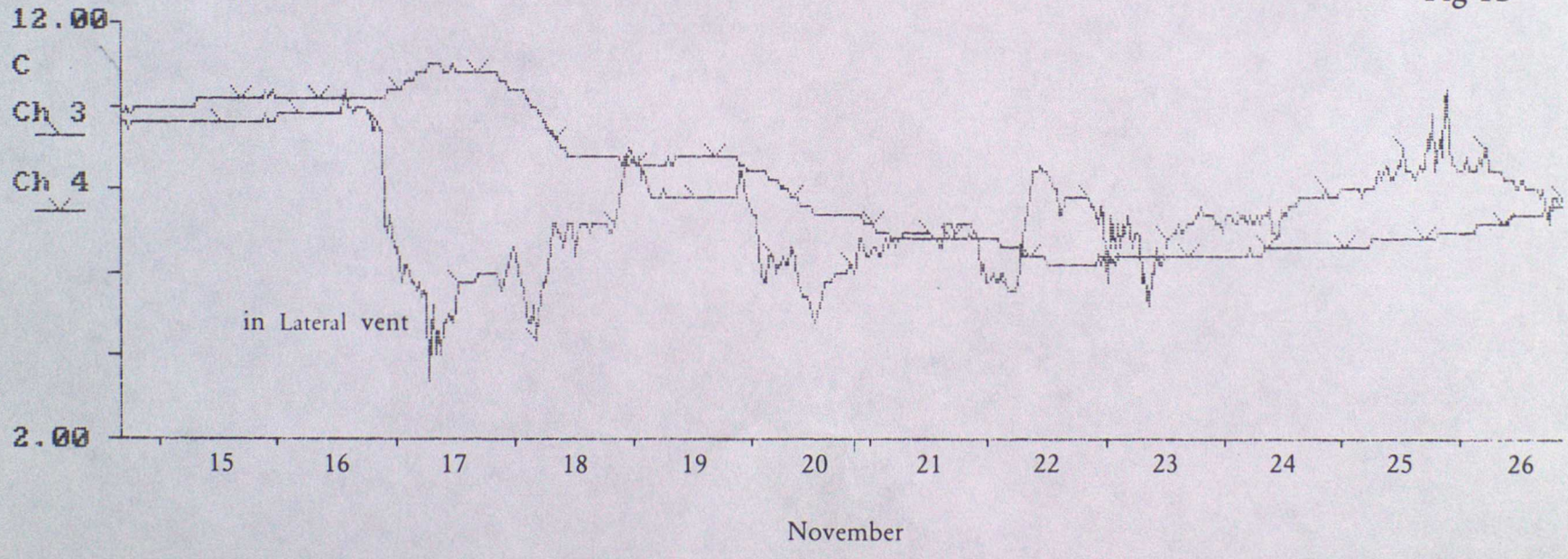
Stack Temperatures

Fig 1a




Stack Temperatures

Fig 1b



Stack Surface Moisture

Fig 1c

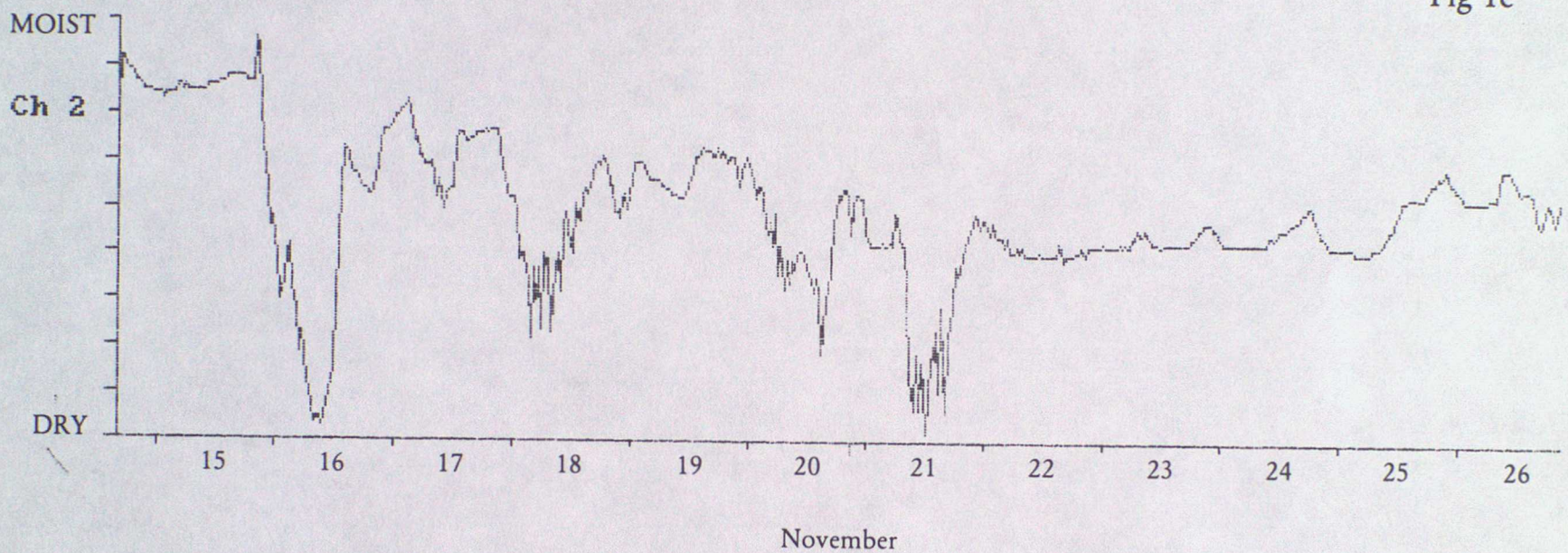


Fig. 2

Weekly Mean Temperatures: Ware Store, 1986/87

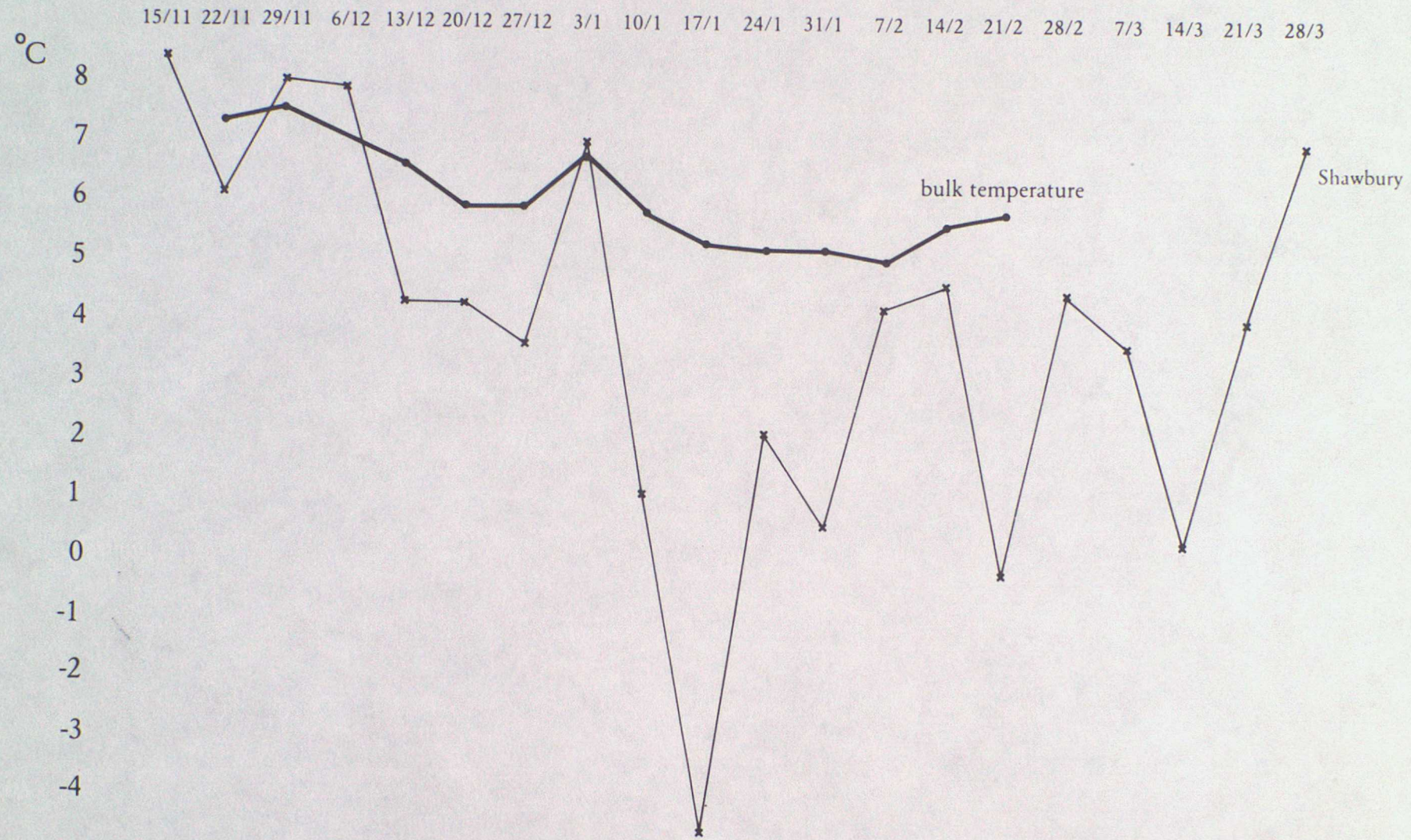
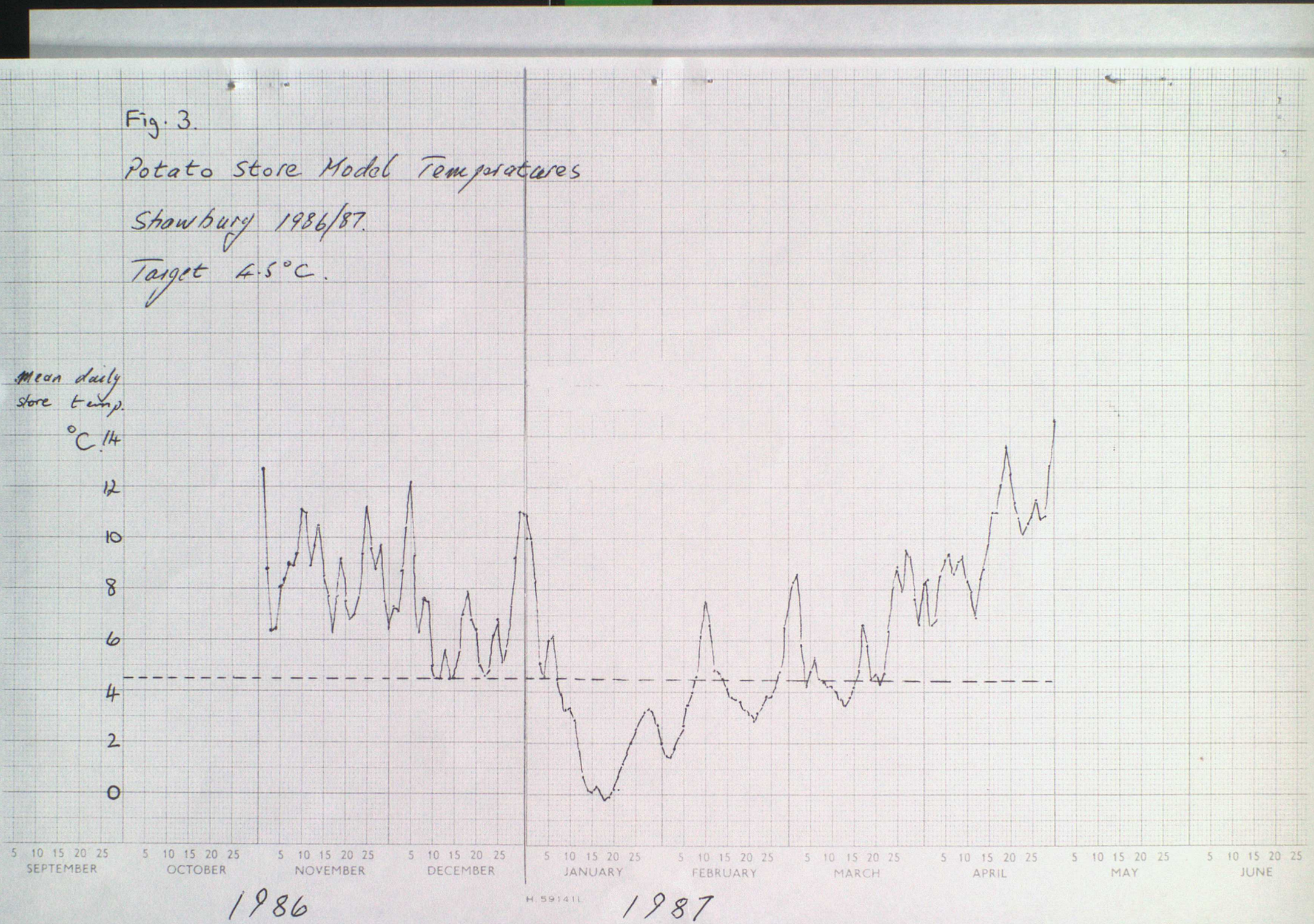


Fig. 3.

Potato Store Model Temperatures

Shawbury 1986/87.

Target 4.5°C.

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